US EPA ARCHIVE DOCUMENT

World Trade Center Indoor Environment Assessment: Selecting Contaminants of Potential Concern and Setting Health-Based Benchmarks

May 2003

Prepared by the Contaminants of Potential Concern (COPC) Committee of the World Trade Center Indoor Air Task Force Working Group

Contributors:

U.S. Environmental Protection Agency
Mark Maddaloni
Charles Nace
Peter Grevatt
Terry Smith
Dore LaPosta
John Schaum
Dana Tulis
Jennifer Hubbard

New York City Department of Health and Mental Hygiene
Nancy Jeffery
Ken Carlino
Jeanine Prudhomme
Chris D'Andrea
Caroline Bragdon
James Miller

Agency for Toxic Substances and Disease Registry
Sven Rodenbeck
Danielle DeVoney

New York State Department of Health
Robert Chinery

Occupational Safety and Health Administration
David Ippolito
Dan Crane

Fraction Transferred from Surface to Skin (FTSS, unitless) - Rodes et al. 2001 conducted hand press experiments on particle transfer to dry skin and measured transfers with central values of about ~~of~~ 10% from carpets and 50% from hard surfaces. These are considered representative of the WTC situation and were adopted in this assessment for transfers to hands leading to ingestion. Rodes et al. presented some data suggesting that transfers to wet skin (which would be associated with mouthing behavior) would be higher than dry skin, but these results were not used since they appeared less reliable.

Surface Area (SA, cm^2/event) - This is the skin area contacted during the mouthing event. The OPP default is 20 cm^2 based on the area of a child's 3 fingers. Total skin surface area increases by about 3 fold from age 2 to an adult (EPA, 1997). Average area of both hands for an adult is about 900 cm^2, so it would be about 300 cm^2 for a 2 year old. Assuming 3 fingers of one hand represents about 5% of the total area of both hands, it would increase from 15 cm^2 to 45 cm^2 from age 2 to adult. On this basis, the SA values used here are assumed to start at 15 cm^2 and increase linearly to 45 cm^2 at age 17 and remain constant after that.

Frequency of hand to mouth events (FQ, events/hr) - The OPP defaults suggest 9.5 events/hr for toddlers, based on observations at day care centers. This will decline with age, but very little data are available for other ages. Michaud et al (1994) assumed a mouthing frequency of twice per day for adults. It was decided to step down this frequency as follows: 1 to 6 yr - 9.5 times/hr, 7 to 12 - 5 times/hr, 8 to 18 yr - 2 times/hr and 19 to 31 yr - 1 time/hr.

Saliva Extraction factor (SE, unitless fraction) - The fraction transferred from skin to mouth will depend on the contaminant, mouthing time and other behavioral patterns. The OPP default is 50%, based on pesticide studies. Michaud et al (1994) assumed that all of the residues deposited on the fingertips would be transferred to the mouth, twice per day. In the Binghamton re-entry guideline derivation, a range of factors were used: 0.05, 0.1, and 0.25 representing the fraction of residue on hand that is transferred to the mouth (Kim and Hawley, 1985). For purposes of this assessment, the OPP default of 50% was selected for all ages.

Exposure Time (ET, hr/d) - Same as dermal contact, see discussion above.

Body Weight (BW, kg) - Same as dermal contact, see discussion above.

3.3 Dissipation

The surface loading of the contaminant in the dust is likely to diminish over the 30 year exposure period as a result of volatilization, chemical degradation, surface cleaning and transfers to skin/clothing. While some redeposition will also occur, the net long term effect should be a gradual decline. The discussion below provides a review of the literature related to this issue.

Several studies indicate that the main source of new dust indoors is track-in from footwear. Thatcher and Layton (1995) found a mass increase on tracked but not cleaned/vacuumed floor surfaces of 0.01 grams/day-m^2 for linoleum, 0.15 for upstairs carpet and 0.31 for downstairs carpet. They reported a value for the front doormat of 6.2 grams /day-m^2. Allot (1992) also indicated that the main mechanism for introduction of dust indoors is tracking by footwear and noted a smaller contribution from deposition dust particles suspended in air. Without regular indoor cleaning the dust inputs would accumulate. With time, they would likely become noticeable or objectionable to the inhabitants, prompting cleaning. Lioy (2002) indicates that in a survey of 36 homes, an average time since the last cleaning was 14.2 days (range 1-150 days). Roberts et al. (1999) determined that the median value of dust loading on 11 carpets before cleaning was 1.3 g/m^2. This agrees with Camann and Buckley's (1994) estimate of the

US EPA ARCHIVE DOCUMENT

median surface loading on 362 carpets of 1.4 g/m^2. Lioy et al. (2002) report ranges of dust loadings in homes from 0.05-7 g/m^2 for floors and <1 to 63 g/m^2 for rugs. See summary in Table 2.

Table 2. Dust Loads on Indoor Surfaces

	Dust Load (: g/cm^2)	Reference
Hard Surfaces	5-700 floors	Lioy et al. (2002)
Soft Surfaces	130 - median for carpets before cleaning (n=11) 10 - median for carpets after cleaning (n=10) 140 - median for carpets (n=362) <100 to 6300 - range for rugs	Roberts et al. (1999) Roberts et al. (1999) Camann and Buckley (1994) Lioy et al. (2002)

Elevated non-porous surfaces such as walls, table tops, counters, etc. receive much of their dust loads from deposition of suspended dust. The mean dustfall rate in 100 American homes in five cities was 0.02 g/day-m^2 (Schaefer et al 1972, quoted in Roberts, Budd, et al. 1992) . This indicates that the dust inputs to these surfaces are considerably smaller than track-in for carpets near entryways.

In order to maintain a fairly constant dust loading on surfaces, dust would have to be removed by cleaning at a rate equal to the rate of input from outside sources. Otherwise dust will accumulate and probably further prompt cleaning because it would be noticeable or objectionable. Assuming an input of 0.31 grams /day$_{-1}$ m$_{-2}$ for track-in to a downstairs carpet (Thatcher and Layton (1995)), dust must be removed by cleaning at this rate to maintain a constant dust load on carpet. At a track-in rate of 0.31 g/day/m^2, an initially clean carpet would require about 5 days to achieve a dust loading of 1.3 g/m^2.

If cleaning occurred on a periodic basis as it normally does, newly tracked-in dust would continually be mixed with and removed by cleaning with dust in the carpet from previous tracking events. With continued cleaning eventually the dust reservoir (from past tracking events) would be replaced with newly tracked-in dust. This means that any initial, residual load of dust containing contaminants in a carpet would be gradually removed over time with periodic cleaning and no new significant input of contaminated dust. Roberts et al. (1999) determined that the residual lead loading in carpets could be reduced by 90 to 99% in 6 months by removing shoes on entering (lead was being tracked in from the outside), use of a doormat, and use of an efficient vacuum twice a week. They determined that vigorous vacuuming was efficient in removing the contaminated dust reservoir from carpets. If a carpet is initially loaded with a contaminated dust, a half-life for its removal can be calculated assuming 90% removal in 6 months using the Roberts et al. (1999) data. This results in a 2-month half-life for dust removal from carpets using vigorous cleaning by vacuuming. It would take roughly 12 months to reduce the initial contaminant load by 99.9% using the above scenario. With no new, significant inputs of contaminated dust to a carpet an initial, residual load would be reduced over time with regular vigorous cleaning.

Roberts (1999) also determined that the dust on the surface of 11 carpets could be reduced by 90% in 1 week with the use of a Hoover Self-Propelled Vacuum with Embedded Dirt Finder (HSPF). The pre- and post-cleaning surface loadings were as follows: pre-cleaning fine dust loading: min. 0.32 g/m^2, max. 14.4 g/m^2, median 1.30 g/m^2; final fine dust loading: min. 0.019 g/m^2, max. 0.289 g/m^2, median 0.102 g/m^2. A cumulative vacuuming rate of 6 to 45 min/m^2 of vacuuming with the HSPF removed deep dust from these carpets. The median surface loadings of fine dust in these carpets were reduced by 91%, in 1 to 15 hours of cumulative vacuuming

US EPA ARCHIVE DOCUMENT

ED_006060A_00001928-00003

The above analysis deals with a carpeted surface that can act as a dust reservoir and which is a difficult surface to clean. Non-porous surfaces such as floors and tables, etc. don't have the same degree of storage potential for dust and are easily cleaned. These surfaces will have a faster removal half-life than the approximately 2 months for carpets calculated above. However, they may get re-contaminated from dust re-suspension from the carpets (carpets become the source of contamination) until the carpet contaminant load is reduced.

Further data concerning the removal half-life of dioxins in indoor dust is available from the study of the Binghamton State Office Building (BSOB) (NYSDOH 2002). The building had closed in February 1981 after an intense transformer fire spread an oily soot contaminated with polychlorinated biphenyls (PCBs), polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) throughout the 18-story structure. After extensive decontamination, testing and reconstruction, the BSOB was reopened late in 1994. Pre-occupancy sampling in July 1994 found that PCB and PCDD/F levels in air and on surfaces in workspaces were considerably less than the guidelines set for reoccupancy. In fact, they were similar to levels found in buildings that have never experienced a transformer fire. Seven rounds of dust wipe sampling of tops of in-ceiling light fixtures were performed post-occupancy. PCDD/F levels on the tops of in-ceiling light fixtures averaged 1.1 nanograms per square meter at the final round of sampling, less than any previous measurements. The seven dust wipe sampling rounds indicated a gradual decline of PCDDs over-time on the light fixtures (see Figure 1). Since reoccupancy, surfaces above the ceiling were cleaned twice, once before the March 1997 sampling and again before the sixth round of sampling in August 1998. Since reoccupancy, average PCDD/F levels in dust on light fixtures have declined steadily by about one-half every 20-22 months (a half-life of 20-22 months).

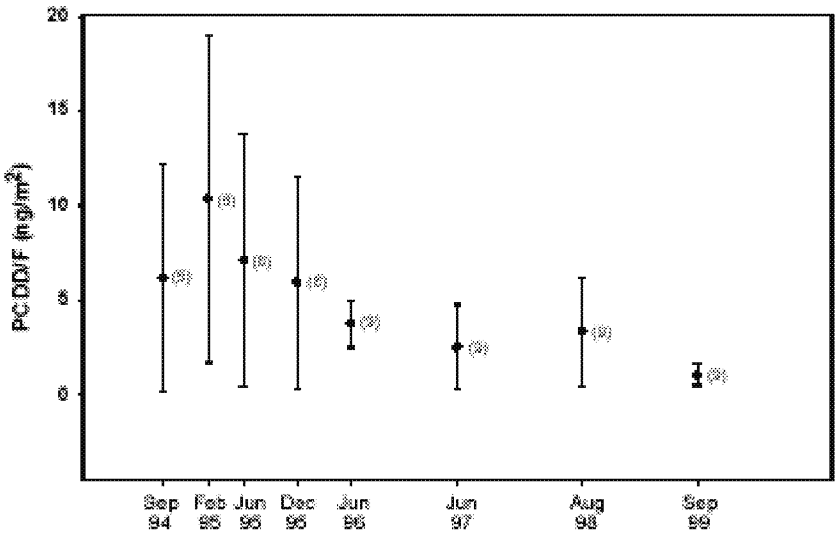

Figure 1. Average PCDD/F levels on the tops of light fixtures since September 1994. Bars are the 95% confidence interval for the means. The numbers in parentheses are the number of samples for each date.

US EPA ARCHIVE DOCUMENT

ED_006060A_00001928-00004

The BSOB PCDD dust half-life value shown above was based on dust wipe sampling of the tops of light fixtures which were inaccessible to regular cleaning and only cleaned twice in 5 years. The mechanism of removal of the contaminated dust was probably a combination of cleaning, resuspension and dilution with uncontaminated dust (and possibly some volatilization). This half-life is a conservative, upper bound estimate of a removal half-life for dioxins in dust for areas that are cleaned routinely (such as would be expected were people would have daily contact). The BSOB half-life should be acceptable and conservative for use in the COPC risk assessment scenario which addresses exposure to accessible surfaces. It will capture the mechanism of dust removal from a residence due to regular cleaning that is discussed by Roberts et al. (1999) and Allot (1992) cited above and is a slower removal of dioxins in dust than would be predicted using these carpet vacuuming studies.

Further support for considering dissipation is presented below:

- The OPP guidance (EPA, 1997a and EPA, 2001a) uses a "dissipation" factor to account for degradation and other loss mechanisms after pesticide application. Similarly, Durkin et al (1995) has proposed a time-dependent transfer coefficient method for lawn treatment pesticides.
- Michaud et al (1994) proposed a mass balance model which accounts for losses from surfaces associated with building clean-ups.

Based on the above discussion, there is strong support for considering dissipation in setting criteria for building clean-ups. The recently completed study at the Binghamton State office Building described above found that dioxin has dissipated over time according to first order kinetics with a 20 to 22 month half life. As discussed above this dissipation is thought to occur from a combination of cleaning, resuspension and dilution with uncontaminated dust (and possibly some volatilization). These same physical dissipation processes would apply to other compounds addressed in this study as well. Therefore the other compounds were assumed to dissipate at the same rate as dioxin. Note that this leads to some overestimate of risk for the organic compounds with higher volatility than dioxin. In summary, a 22 month half life (decay rate constant of 0.38 yr^{-1}) was adopted here and assumed to apply to all contaminants. Exposures were calculated in a in a series of time steps where the residue level was assumed to dissipate according to first order kinetics:

$CSL = CSL_{initial}\ e^{-kt}$
CSL = Contaminant Surface Load (: g/cm$^{2)}$
$CSL_{initial}$ = Initial Contaminant Surface Load (: g/cm$^{2)}$
k = Dissipation Rate Constant (yr^{-1})
t = Time (yr)

3.4 Calculating Clearance Criteria

The dose rates for dermal contact and ingestion were used to estimate cancer risk and noncancer hazard. The clearance criteria for surface dust loadings were derived by adjusting the levels iteratively until the risks reached the target levels. Cancer risks and noncancer hazards were calculated as follows:

Cancer Risk = LADD * CSF

Noncancer Hazard = ADD/RfD

US EPA ARCHIVE DOCUMENT

ED_006060A_00001928-00005